Volume : 1 | Issue : 6 | June 2012 ISSN - 2250-1991

Research Paper Engineering

Study on the corrosion inhibition of mild steel by azole derivative, phosphono derivative and bivalent cation

*V. Manivannan ** N. Chithralekha

* Professor & Head, Paavai College of Engineering, Namakkal,Tamilnadu

** Department of Physics, Mahendra College of Engineering, Salem, Tamilnadu, India

ABSTRACT

Corrosion inhibition by new triazole derivative, phosphonic acid derivative and Zn2+ on mild steel in aqueous media has been investigated by weight loss and potentiodynamic polarization methods. The experimental results obtained reveal that among the three inhibitors triazole derivative is the best effective inhibitor and the inhibition efficiency is found to be in the following order: 1-(2-thienylcarbonyl)benzotriazole (TCBT) > Zn2+ > 2- phosphonoacetic acid (2-PAA). The variation in inhibitive efficiency mainly depends on the type and nature of the substituents present in the inhibitor molecule.

Keywords : Mild steel, Benzotriazole, Phosphonic acids, Corrosion, Potentiodynamic polarization, Inhibition

1. INTRODUCTION

Iron and its alloys which are widely used in a lot of industrial processes could corrode during these acidic applications particularly with the use of hydrochloric and sulphuric acid. Water is the most commonly used cooling fluid to remove unwanted heat from heat transfer surfaces. At the present time, there is a strong demand for better utilization of the limited water supplies that is mainly due to population growth and increasing development. Due to this, open recirculating cooling water systems that reuse cooling water are frequently used at large central utility stations, at chemical, petrochemical and petroleum refining plants, in steel and paper mills and at all types of processing plants. Open recirculating cooling water systems continuously reuse water that passes through the heat transfer equipment. Water contains dissolved and suspended forms of solids, organic matters and gases. Finally, the open recirculating system, with longer holding times at higher temperatures in the presence of higher dissolved solids concentrations, produces more severe corrosion and scale. Corrosion inhibitors may be divided into three broad classes, namely oxidizing, precipitation and adsorption inhibitors [1]. Compounds containing nitrogen, oxygen, sulphur and phosphorous in the conjugated system have particularly been reported as efficient corrosion inhibitors [2-7]. From the above point of view, the present work aimed to give comparative study by testing the trizaole derivative namely 1-(2-thienylcarbonyl)benzotriazole (TCBT) with 2-Phosphonoacetic acid (2-PAA)[8,9] and bivalent cation Zn2+ as corrosion inhibitors for mild steel in aqueous media by using Weight loss measurements and Electrochemical techniques.

2. EXPERIMENTAL

2.1 Specimen preparation and Structure of the Inhibitors

Mild steel samples with the composition C-0.13%, P-0.032%, Si-0.014%, S-0.025%, Mn-0.48% and balance Fe were used. For each electrochemical study, specimens of size 1.0 cm x 1.0 cm x 0.3 cm were cut, embedded in epoxy resin and mechanically polished with silicon carbide papers (from grades 120 to 1,200) followed by then washing with double distilled water, degreasing with acetone and drying at room temperature. For weight loss measurements metal specimens of 4.0 cm x 2.0 cm x 0.2 cm dimension were used.

The name and structure of the inhibitors are given in Figure-1. Sample water which should be more corrosive in nature was chosen as the test solution for all the experiments. The typical analysis of this electrolyte is as follows: pH-6.78, Temperture – 28 °C , Total hardness – 332 ppm, Alkalinity – 316 ppm, TDS – 586 ppm, respectively.

2.2 Weight loss measurements

Mild steel specimens in triplicate were immersed in ground water at room temperature for each inhibitor concentration for 7 days. The specimens were removed, rinsed in double distilled water and acetone then kept in a desiccator. Then the weight loss was determined in order to calculate the inhibition efficiency using the formula,

$$IE(\%) = \frac{W_0 - W_i}{W_0} \times 100 \qquad \text{------------ (1)}$$

Where, W0 and Wi are the weight loss in the absence and presence of inhibitor respectively.

2.3. Electrochemical studies

All the electrochemical measurements were performed using an Electrochemical Workstation (Model No: CHI 760, CH Instruments, USA). The potentiodynamic polarization studies were carried out from -1200 to 0 mV at a scan rate of 0.1 mV s-1.

3. RESULTS AND DISCUSSION

3.1 Weight loss measurements

The results of weight loss measurements for mild steel in ground water in the absence and presence of various concentrations of TCBT, 2-PAA and Zn2+ are listed in Table 1. There is a significant decrease in the corrosion rate with increase in concentration of each inhibitor and the extent of inhibition depends on the nature and concentration of the inhibitor. The optimum concentration was evaluated based on inhibition efficiency: for TCBT, 2-PAA and Zn2+ , these are 16, 12 and 75 ppm respectively. TCBT, 2-PAA and Zn2+ have a maximum inhibition efficiency of 70.7, 61.96 and 67.7% respectively. Among the three inhibitors the corrosion inhibition efficiency of TCBT shows maximum, it may due to the structure and substituent present in the inhibitor.

3.2. Potentiodynamic polarization studies

Figures 2-4, present polarization curves for mild steel electrode in ground water medium, in the presence and absence of studied inhibitors at various concentrations. The inhibition efficiency increases appreciably with increase in inhibitor concentration up to the optimum level, after which it decreases. The optimum concentrations were evaluated based on the inhibition efficiency. Both the cathodic and anodic reactions on mild steel electrode were inhibited in the presence of studied compounds.

Tafel polarization curves for mild steel in ground water medium with different concentrations of TCBT are shown in Figure-2. As it can be seen, both cathodic and anodic reactions of mild steel corrosion were inhibited with the increase up to the optimum level of TCBT concentration in ground water environment. TCBT suppressed the cathodic reaction to greater extent than the anodic one and this behavior of TCBT inhibitor shows that mixed type with cathodic predominance. TCBT shows better inhibition efficiency and the optimum concentration found to be 16 ppm, icorr and inhibition efficiency were found to be 3.55μA cm-2 and 71.8% respectively. The corrosion rate decreases up to the optimum concentration of TCBT after that it shows significant increase.

The anodic and cathodic potentiodynamic polarization curves for mild steel in ground water medium in the absence and presence of different concentrations of 2-PAA at 30°C is represented in Figure-3. From the figure depicted, it is evident that an appreciable decrease in both cathodic and anodic current were observed. Addition of 2-PAA to the test solution showed a shift in corrosion potential towards anodic direction corresponding to the predominant control of anodic reaction. The corrosion current was decreased considerably in the presence of 2-PAA. The value of corrosion rate of mild steel in the presence of inhibitor was much smaller than that in the absence of an inhibitor. In the presence of 2-PAA, the inhibition efficiency was about 62.6 % and the corrosion rate was found to be 2.15 mpy at the optimum concentration of 12 ppm.

The Tafel plots for mild steel in ground water in the absence and presence of Zn2+ is shown in Figure- 4. As it can be seen, the cathodic reactions of mild steel corrosion were inhibited with the increasing concentrations of Zn2+ up to the optimum level in ground water environment. Zn2+ suppressed the cathodic reaction to a greater extent. When compared with BTA, Zn2+ shows better inhibition efficiency and the optimum concentration found to be 75 ppm, icorr and inhibition efficiency were found to be 3.98 μA cm-2 and 68.4%. The corrosion rate decreases up to the optimum concentration (75 ppm) of Zn2+ after that the corrosion rate increases significantly. The corrosion parameters such as corrosion potential (Ecorr) and corrosion current density (icorr), obtained fromTafel plots are presented given in Table 2.

4. CONCLUSIONS

All the examined benzotriazole derivative, phosphono derivative and zinc were found to be good corrosion inhibitors for mild steel in ground water medium. The order of inhibition efficiencies of studied derivatives were found in the order: TCBT < Zn 2+ < 2-PAA. Studied phosphono derivative (2-PAA) was acting as mixed-type inhibitors with anodic predominance, benzotriazole derivative (TCBT) was acting as mixed-type inhibitors with cathodic predominance and at the same time Zn2+ was acts as cathodic inhibitors. A good agreement was observed between weight loss measurements coupled with electrochemical measurements.

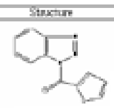
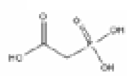
Name	Abbreviation	Structure
1-(2-Thienylcarbonyl)-benzotriazole	TCBT	
2-Phosphonoacetic acid	2-PAA	

Figure 1: Structures and Names of the inhibitors

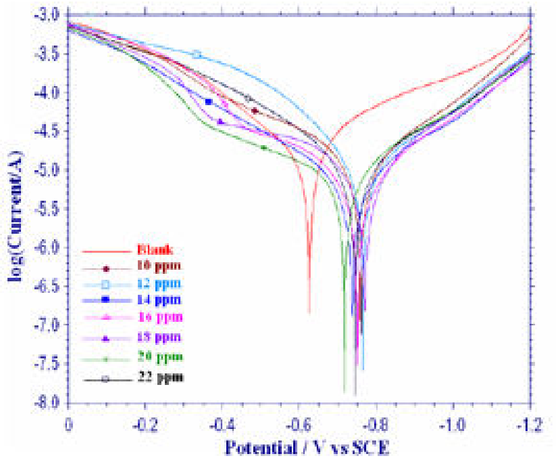


Figure 2: Potentiodynamic polarization curves of mild steel in ground water in the absence and presence of various concentrations of TCBT at 30 °C

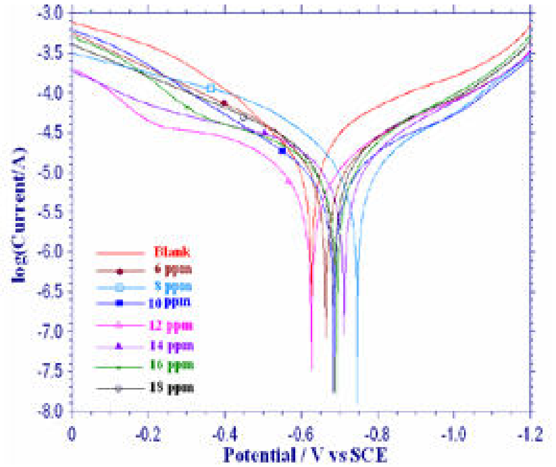


Figure 3: Potentiodynamic polarization curves of mild steel in ground water in the absence and presence of various concentrations of 2-PAA at 30 °C

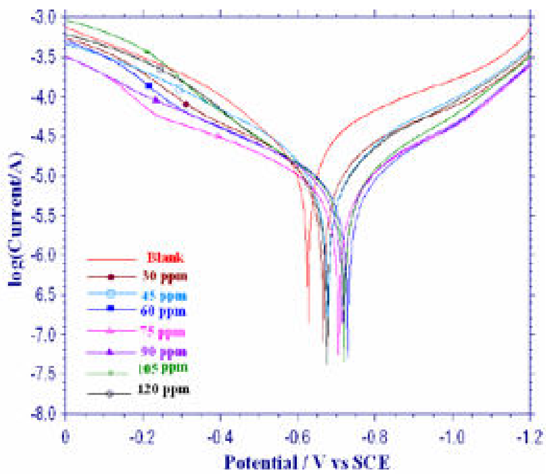


Figure 4: Potentiodynamic polarization curves of mild steel in ground water in the absence and presence of various concentrations of Zn2+ at 30 °C

Table -1 Weight loss measurements of mild steel in ground water in the absence and presence of various concentrations of triazole derivatives at 30 °C.

Inhibitor	Inhibitor conc. (ppm)	Corrosion rate (mpy)	Inhibition efficiency (%)
Blank	-	6.60	-
TCBT	10	3.91	40.75
	12	3.31	49.84
	14	2.35	64.30
	16	1.91	70.71
	18	2.51	61.96
	20	2.95	55.30
	22	3.42	48.18
2- PAA	6	3.85	42.27
	8	3.43	48.03
	10	2.75	58.33
	12	2.51	61.96
	14	2.90	56.06
	16	3.37	48.93
	18	4.01	39.24
Zn^{2+}	30	3.2	51.51
	45	2.95	55.30
	60	2.30	65.15
	75	2.1	67.7
	90	2.25	65.9
	105	2.51	61.96
	120	2.76	58.18

Table - 2 Potentiodynamic polarization parameters of mild steel in ground water in the absence and presence of various concentrations of benzotriazole derivatives at 30 °C

Inhibitor	Inhibitor conc. (ppm)	E_{corr} (mV)	i_{corr} (μA cm^{-2})	Corrosion rate (mpy)	Inhibition efficiency (%)
Blank	-	-640	12.59	5.75	-
TCBT	10	-795	7.41	3.38	41.1
	12	-744	6.12	2.79	51.4
	14	-740	4.38	2.00	65.2
	16	-775	3.55	1.62	71.8
	18	-760	4.74	2.16	62.4
	20	-725	5.60	2.56	55.5
	22	-745	6.49	2.96	48.5
2-PAA	6	-669	7.23	3.30	42.5
	8	-744	6.38	2.91	49.3
	10	-681	5.15	2.35	59.0
	12	-627	4.71	2.15	62.6
	14	-714	6.07	2.77	57.7
	16	-713	6.42	2.93	49.0
	18	-684	7.50	3.42	40.4
Zn^{2+}	30	-655	6.02	2.75	52.2
	45	-690	5.62	2.56	55.4
	60	-750	4.26	1.94	66.2
	75	-705	3.98	1.81	68.4
	90	-740	4.16	1.90	66.9
	105	-740	4.78	2.18	62.0
	120	-690	5.25	2.39	58.3

REFERENCES

1 Sykes, J M. (1990). Silver jubilee review 25 years of progress in electrochemical methods: Br. Corros. J, 25, 175-189. doi: org/10.1179/000705990798269577. | 2 Hynh, N., Bottle S E., Notoya T., & Schweinsberg D P. (2002). Inhibition of copper corrosion by coatings of alkyl esters of carboxy benzotriazole: Corros. Sci., 44, 2583-2596. doi: org/10.1016/s0010-938x(02)00014-8. | 3 Ozcan, M., Dehri, I., & Erbil, M. (2004). Organic sulphur containing compounds as corrosion inhibitors for mild steel in acidic media: correlation between inhibition efficiency and chemical structure: Appl. Surf. Sci., 236, 155-164. doi: org/10.1016/j.apsusc.2004.04.017. | 4 Larabi, L., Harek, Y., Traisnel, M., & Mansri. A. (2004). Synergistic influence of poly(4-vinyl pyridine) and potassium iodide on inhibition of corrosion of mild steel in 1m HCl: J. Appl. Electrochem.34, 833-839. Doi: 10.1023/ B: JA. H0000035609.09564.e6. | 5 Khaled, K F. (2004). An electrochemical study for corrosion inhibition of iron by some organic phosphonium chloride derivatives in acid media: Appl. Surf. Sci. 230, 307-318. Doi: org/10.1016/j.apsusc.2004.02.041. | 6 Babic-Samardzija, K., Khaled, K F., & Hackerman, N. (2005). Investigation of the inhibition action of O-, S- and N- dithio carbamato (1,4,8,11- tetrazacyclotetradecane) cobalt (III) compleces on the corrosion of iron HClO4 acid. Appl. Surf. Sci.240, 327-340. Doi: org/10.1016/j.apsusc. 2004.07.075. | 7 Chetouani, A., Hammouti, B., Aounti, A., Benchat, N., & Benhadda, T. (2002). New synthesized pyridazine derivatives as effective inhibitors for the corrosion of pure iron in HCl medium.Prog. Org. Coat. 45, 373-378. Doi: org/10.1016/s. 300-9440(02) 00123-6. | 8 Gopi, D., Govindaraju, K M., Collins Arun Prakash, V. , Angeline Sakila, D M., & Kavitha, L. (2009). A study on new benzotriazole derivatives as inhibitors on copper corrosion in ground water. Corros. Sci., 51, 2259-2265. Doi: org/10.1016/ j. corsci.2009.06.008. | 9 Gopi, D., Govindaraju, K M., Collins Arun Prakash, V., Manivannan, V., & Kavitha, L. (2009). Inhibition of mild steel corrosion in ground water by pyrrole and theinyl carbonyl benzotriazole. J. Appl. Electrochem., 39, 269-276.doi: 10.1007/s10800-008.9666-4.